REMARKS

In the office action, the examiner rejected Claims 16, 21-23 and 40 under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. It is stated that, in Claims 16 and 40, the feature "wherein, in the drilling operation, when hardness H of the workpiece W is lower than 500 [Hv], a peripheral velocity V of the drill D is higher than (175 - H / 4) [m/min] and a feed amount of the drill per one revolution is smaller than 0.03 mm" is not described in the instant specification. Further, it is stated that, in Claims 16 and 40, the feature "when the hardness H of the workpiece W is higher than 500 [Hv], the peripheral velocity V of the drill D is higher than 50 [m/min] and the feed amount of the drill D per one revolution is smaller than 0.03 mm" is not described in the instant specification.

In the previous amendment of Claim 16 and in new Claim 40, the applicant has inadvertently recited that "the feed amount of the drill D per one revolution is smaller than 0.03 mm" where the value "0.03 mm" should be --0.3 mm-- as described in the paragraph [0071] in the specification. Accordingly, the applicant has amended Claims 16 and 40 concurrently herewith to correct the numerical value to --0.3 mm--. As noted above, the applicant has submitted concurrently herewith a request for continued examination (RCE) under 37 CFR 1.114 with a prescribed fee so that the amended set of claims be examined.

In the office action, the examiner rejected Claims 16, 21-23 and 40 under 35 U.S.C. 103(a) as being unpatentable over Blechner (U.S. Patent No. 3,117,042). In the response to the previous office action, the applicant has added the limitations to Claim 16 and 40 to more clearly differentiate the present invention from the technologies disclosed by the prior art.

More specifically, the applicant has added the limitations to Claim 16 so that the features of the present invention reside in that (1) the drilling operation on a machined surface of the workpiece to impart a large local strain to the machined surface, (2) drilling operation causes the machined surface of the workpiece to be subjected to a plastic working with a true strain of at least 1, such that said ultrafine crystal layer is formed on the machined surface, (3) in the drilling operation, when hardness H of the workpiece W is lower than 500 [Hv], a peripheral velocity V of the drill D is higher than (175 - H / 4) [m/min] and a feed amount of the drill per one revolution is smaller than 0.3 mm, and when the hardness H of the workpiece W is higher than 500 [Hv], the peripheral velocity V of the drill D is higher than 50 [m/min] and the feed amount of the drill D per one revolution is smaller than 0.3 mm, and (4) the drilling operation is performed for the workpiece made of steel material with a material temperature at the machined surface being held in a range which is higher than an Ac1 transformation point of the steel material and lower than a melting point of the steel material.

It should be noted that, in the present invention, it is essential that, when the workpiece is constituted by a metallic material, (a) the drilling operation on a machined surface of the workpiece is conducted under the condition noted in the feature (4) in combination with (b) to impart a large local strain to the machined surface, (2) drilling operation is conducted by the condition defined in the feature (3). Only when such a combination is established, the machined surface of the workpiece is subjected to a plastic working with a true strain of at least 1, thereby forming the ultrafine crystal layer on the machined surface. This effect is exemplified by, for example, an article "A microstructural investigation of the surface of a drilled hole in carbon steel", J.G. Li, M. Umemoto, Y Todaka, K. Tsuchiya, Acta Materialia, 2006, a copy of which is attached as a reference.

The features of the present invention defined in Claim 40 are the same with respect to the features (1)-(3) of Claim 16 noted above. Instead of the feature (4) of Claim 16 noted above, the present invention defined in Claim 40 includes the feature (5) that the drilling operation is performed on the surface of the workpiece made of a non-steel material with a material temperature at the machined surface being held in a range which is higher than substantially half a melting point of the non-steel material and is lower than the melting point of the non-steel material.

Again, it should be noted that, in the present invention, it is essential that, when the workpiece is constituted by a non-steel

metallic material, (a) the drilling operation on a machined surface of the workpiece is conducted under the condition noted in the feature (5) in combination with (b) to impart a large local strain to the machined surface, (2) drilling operation is conducted by the condition defined in the feature (3). Only when such a combination is established, the machined surface of the workpiece is subjected to a plastic working with a true strain of at least 1, thereby forming the ultrafine crystal layer on the machined surface.

The cited Blechner reference is directed to the heat-treatment of metals for hardening. As recited in Claims 16 and 40, the present invention is directed to the drilling operation to improve the hardness, etc., of the machined surface of the workpiece. Rather than the drilling operation, the Blechner reference shows the pressing operation by a machine tool, which is mechanically different from the drilling operation and is not able to form an ultrafine crystal layer even when exerting the true strain greater than 1 under the temperature condition identical to the present invention. Especially, the present invention includes the feature (3) noted above which specifically defines the relationship among the hardness of the workpiece and the peripheral velocity and feed amount of the drill.

In the office action and the advisory action, the examiner indicated that, in addition to the pressing operation, the cited Blechner reference further shows that the several machining processes, such as reaming, can be used, and thus not limited to

the embodiment of pressing operation. The applicant respectfully submits that even though the several machining processes including the "reaming" are disclosed by the cited Blechner reference, the present invention is not obvious as discussed below.

Each of the several machining processes including the "reaming" disclosed by the cited Blechner reference is not a process that produces a hole by a drilling operation during which a very high pressure is applied to a workpiece. For example, with respect to the reaming operation, which is an operation somewhat similar to that of the drilling operation, this process is to enlarge or shape the hole that has been produced in advance. In contrast, the drilling is to create a new hole on a workpiece.

Namely, since the drilling is to produce a hole on the workpiece without any prefabricated holes, the drill digs into the workpiece, thus provides a high pressure on the workpiece. In contrast, since the reaming is merely to cut the prefabricated hole, it does not provides such a high pressure to the workpiece. In the example using the reamer indicated by the cited Blechner reference ("Saw Blading" in column 5, lines 39-65), the pressure between the tool (reamer) and the workpiece is about 500g which is relatively small. The pressure applied to the workpiece in the other machine processes in the cited Blechner reference also show a relatively small amount such as 0-20g/mm^2.

With respect to the drilling operation, the applicant has measured as to how much load is applied to the workpiece and found

that thrust force is 318-518N and torque is 26-33N·cm. Thus, the drilling operation under the conditions prescribed by the present invention provides the pressure which is much larger than that caused by the machine processes of the cited Blechner reference including the reaming.

In the machine process disclosed by the cited Blechner reference, it is not possible to provide a high distortion to the machined surface of the workpiece since the high enough pressure is not applied to the workpiece. Therefore, in such a condition, even though the machine process is conducted under the temperature higher than the Ac1 transformation point, the ultrafine crystal layer of the present invention is not produced but rather only a new martensite is produced. The attached documents (Photo 1-3) show the experimental results indicating that, without imparting the high distortion to the machined surface of the workpiece, the ultrafine crystal layer of the present invention is not produced but rather only a new martensite is produced, even though the machine process is conducted under the temperature higher than the Ac1 transformation point.

In this experiment, a laser beam is applied to the workpiece and the condition at the location where the laser beam is irradiated is monitored. The workpiece is S55C. With regard to the laser beam condition, an output power is 300W, a laser beam duty ratio is 50% and a exposure location is moved 500mm/min. Under this condition, only the location where the laser beam is

exposed becomes higher than the transformation point Ac1 in temperature. Further, since only the laser beam is applied, the machined surface of the workpiece suffers no distortion.

Photo 1 shows images of the surface of the workpiece when the laser beam is irradiated under the condition noted above. The image in the lower left is obtained through an optical microscope and the image in the lower right is obtained through a scanning electron microscope (SEM). Photo 2 shows the images corresponding to that of Photo 1 but are obtained through a transmission electron microscope (TEM).

According to the images produced by the optical microscope and SEM, the point where the laser beam is irradiated ("White Layer") looks as though an ultrafine crystal layer is formed. At the time (1958) when the cited Blechner reference was filed as a patent application, it might be possible that the inventor had interpreted that the ultrafine crystal layer was formed on the irradiated point. However, as shown by the images obtained by TEM, the point where the laser beam is irradiated is a new martensite rather than the ultrafine crystal layer.

In contrast, Photo 3 shows images of the surface of the workpiece in the drilling process under the conditions defined by the present invention, which are obtained via TEM. As shown by these images, when the workpiece is applied with the drilling operation under the prescribed conditions of the present invention, the machined surface becomes the ultrafine crystal layer.

As discussed above, since the machine processes disclosed by the cited Blechner reference do not include the drilling operation of the present invention, thus it is not possible to impart a large distortion on the machined surface. As a consequence, even though the machine process such as reaming is conducted under the temperature higher than the Ac1 transformation point, the ultrafine crystal layer of the present invention is not produced but rather a new martensite is merely produced.

Since the essential feature is not shown or suggested by the cited Blechner reference, the present invention is not obvious over the cited Blechner reference.

In view of the foregoing, the applicant believes that the instant application is in condition for allowance, and accordingly, the applicant respectfully requests that the present application be allowed and passed to issue.

Respectfully submitted,

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